CONCRETE BLOCK PAVEMENT FOR LOW VOLUME ROADS

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SUMMARY

Concrete block pavement (CBP) is a durable pavement for carrying light as well as heavy loads, and it is being used widely for construction of city streets, parking places, gas stations, container stacking yards, residential areas and low volume roads. This paper presents the findings of a laboratory investigation on structural behaviour of CBP. Plate load and Accelerated Pavement tests were carried out for the evaluation of CBP. Wet Mix Macadam (WMM) has been used as a granular subbase for plate as well as accelerated pavement tests. Plate load test on CBP with the different thickness of WMM without and with the use of jointing sand were carried out and it was found that the reduction in surface deflection was significant for different values of subbase thickness. Pavement deflections taken during the tests were used for determining the structural properties of the pavement. Accelerated tests on 2m wide pavements were also carried out on CBP having WMM subbases in Accelerated Pavement Test facility of the Institute. Falling Weight Deflectometer (FWD) tests were done on the CBP pavements after different repetitions of dual wheel load. The back calculation computer program BACKGA was used for evaluating the moduli of different layers of CBP. It was found that equivalent elastic modulus of concrete block layer increased with increase in subbase thickness and the modulus varied from 700MPa to 3300MPa. Design Charts were developed for low volume roads considering vertical subgrade strain as the criterion for thickness design.

1. INTRODUCTION

Precast Concrete Block Pavements (CBP) are being used in many countries for construction of city streets, parking places, gas stations, container yards, roads for residential areas, low volume roads etc. CBP consists of individual blocks of hand-sized units that are laid on a thin bed of sand overlying a granular/cement treated granular subbases (Figure 1). The blocks are flanked on each side by edge restraints made up of cement concrete. The joint spaces between the blocks vary between 2mm to 4mm and are filled up with sand of specified gradation. When load is applied on the pavement, the sand particles lock the individual block because of the dilatancy of jointing sand upon relative deformation among adjacent blocks. The load spreading ability of a block layer primarily depends on the

'interlocking', which refers to the geometric relationship between one block and its neighbor or the 'lock-up', a phenomenon, which develops in block pavements after a certain amount of time, has elapsed after construction (Clifford, 1984).

Blocks can be arranged in variety of patterns like stretcher, herringbone, basket weave, etc. CBP is comparatively a new concept in road pavement and it is becoming popular in India too.

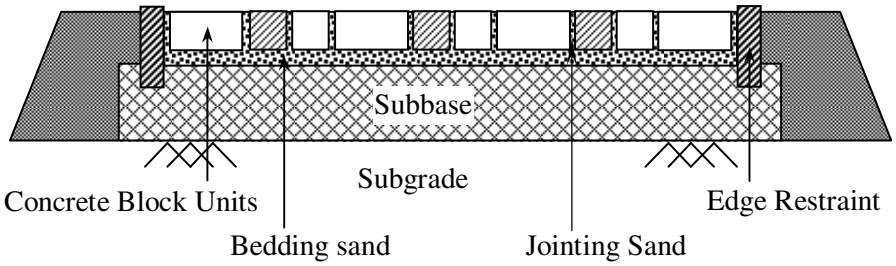


Figure 1. Pavement structure of precast concrete block pavement

In India, the use of precast concrete block pavement started in recent years only. The lack of know how and design practice on precast concrete block pavement in India has acted as a deterrent to its use in various applications like low volume road, city streets, intersections, etc. Also very little research work is carried out in the country to understand its performance and to develop the design parameters based on use of local construction practice.

The present study aims at investigating the structural behavior of concrete block pavements laid over Wet Mix Macadam subbase, a popular granular base course material used in major highways in India.

World wide research on CBP indicated that the modulus values of concrete block layer varied widely from as low as 100MPa to as high as 12,495MPa (Panda, 2001; Shackel and Candy, 1993). Selection of modulus value for the block layer for pavement design is a difficult choice. Effect of different subbase thicknesses on modulus of block pavements requires further examination because of lack of clear guidelines. Therefore, there is a need for investigation on the performance concrete block pavement for their use in low volume roads in order to develop design criteria that would be applicable to low volume roads in India.

2. OBJECTIVES OF THE STUDY

The objective of the study was to determine the structural design parameters for mechanistic design of concrete block pavement because of their increasing popularity in India. It is also intended to determine the effect of the granular subbase on modulus of the block layer. More specifically, the paper includes:

- Evaluation of structural behavior of concrete block pavement (CBP) laid over Wet Mix Macadam granular subbase by means of plate load and accelerated pavement tests.
- Evaluation of equivalent elastic modulus of concrete block layers.
- Development of design thickness chart for CBP.

3. EXPERIMENTAL INVESTIGATION

3.1 Materials

3.1.1 Concrete blocks

For producing concrete blocks, prismatic beam specimens were cast in batches and blocks of dimension 212mm x 106mm x 80mm were cut out from beams with a diamond saw. For each batch, three cubes of size 150mm x 150mm x 150mm were cast along with the beams to determine the strength of the mix. Compressive strength was performed on the cubes after 28 days and the average strength of the mix was 41MPa.

3.1.2 Bedding sand and jointing sand

The locally available sand from the river Kasai having a maximum size of 10mm was selected as the bedding sand in average loose thickness of 50mm. On particle analysis, it was found that it (Table 1) corresponds to Zone III of the Indian Standard (BIS, 1970). Based on the study by Panda and Ghosh (2002a), the river sand was straightaway used as bedding sand and that passing the 1.18mm sieve, was used as jointing sand. Table 1 gives the particle size gradation of bedding sand and jointing sand

Table 1. Bedding and jointing sand particle size distribution

Sieve Size (mm)		10	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Gradation (% Passing)	Bedding Sand	100	97.5	93.3	82.8	68.3	22.8	3.8	0.02
	Jointing sand	100	100	100	100	82.5	27.9	5.0	0.4
Zone III of Indian Standard		100	90-100	85-100	75-100	60-79	12-40	0-10	

3.13 Granular subbase

The granular subbase of Wet Mix Macadam (WMM) meeting the specifications requirement of MORTH (MORTH, 2001) was used in the present study. The aggregates for WMM were collected from five different piles stacked at a nearby crusher plant and re-blended to meet the specification limits (Table 2). Density test under modified compaction was carried out and found to be 2171 kg/m^3 at the optimum moisture content of 8%.

Table 2. Blended particle size distribution and properties of WMM subbase

Sieve Size (mm)		53	40	22.5	11.2	4.75	2.36	0.6	0.075
Gradation (% Passing)	Specified limit	100	95-100	60-80	40-60	25-40	15-30	8-22	0-8
	Blended	100	96.15	66.44	58.62	33.75	17.59	10.95	4.11

4. TEST PROGRAM

The test program on CBP consists of two parts – a) Plate load test and b) accelerated load test

4.1 Plate load test

4.1.1 Test set up

The Test Set up required for the study was made in an open area. This allows testing to be done directly on subgrade close to field conditions. The reaction frame for loading was made of an I section having suitable foundations. Load is applied through a hydraulic jack of 100kN capacity and is transmitted to the pavement through a steel plate of 300mm diameter. The inside dimensions of the test area is 3m x 2m. A brick wall built all around the test bed provided edge restraint for the pavement.

4.1.2 Subgrade

Local soil was used as a subgrade. Particle size distribution and hydrometer analysis (Table 3) were carried out on the soil according to the Bureau of Indian Standard (BIS, 1985a). Plastic limit test (BIS, 1985b) was carried out on the soil and it was found to correspond to CL of the standard and A-2-6 of AASHTO classifications (AASHTO, 1993) respectively. Laboratory compaction test was done to determine optimum moisture content (OMC) and maximum dry density (DD) for standard and modified compaction (BIS, 1983). CBR of the soil was carried out under modified compaction at optimum moisture content and after of 4 days soaking and was found to be 20.58% and 7.53% respectively. The subgrade soil was compacted by a plate vibrator, which could exert a peak load of 10kN over a rectangular area of 250mm x 300mm in layers to a total thickness of 450mm. Density test was conducted on each layer by core cutter method (BIS, 1975) and was found to be more than 98% of modified proctor.

Table 3. Properties of Selected Subgrade

Sieve Size (mm)	4.75	2.36	1.18	0.6	0.3	0.15	75µ	47µ	23µ	9µ	6µ	4µ
%Passing	100	57.34	37.53	25.74	17.35	11.12	7.3	4.55	3.69	2.25	1.96	1.82
Atterberg's Limit	Plastic limit					15						
	Liquid Limit					30						
	Plasticity Index					15						

4.1.3 Subbase

The required quantity of WMM aggregates of different size fractions was mixed in a mixer to achieve a particular thickness with required moisture content and placed on the compacted subgrade. The material was placed and spread evenly avoiding segregation. The aggregates were then compacted with a plate vibrator. After the compaction, the density of the compacted mass was checked by sand cone replacement method (BIS, 1966). The density achieved was found to be more than 98% of the laboratory density using modified compaction (BIS, 1983). The thickness of the compacted WMM subbase was determined as a mean of nine readings obtained by measuring the level difference between the top of the WMM and that of the subgrade, the nine points being chosen both across and along the test pit.

4.2 Accelerated load test

4.2.1 Accelerated pavement test facility (APTF)

The APTF developed by the Transportation Engineering group of the Institute was used in this investigation. It consists of dual wheel set, which can be loaded up to 60kN and is driven by a 20kW, 440V three-phase motor. It can move to and fro in a linear track, 12m long. The test assembly consists of four guide wheels which are arranged in such a manner that the entire load of the structure is shared by the dual wheel and the two rear guide wheels resting on two parallel tracks 2.33m apart. The rear guide wheels and the dual wheel in the center of the test pavement form a tricycle. The loading bin is so designed that most of the dead load comes on the dual wheel. The load from the loading bin is transmitted to the axle of the dual wheel through leaf springs. In the present investigation, rail sections were used as dead load. The total weight coming on the wheels was fixed as 40kN, which corresponds to half of the standard axle load of a truck. A portable weigh-bridge was used to measure the load on the dual wheel.

4.2.2 Falling weight deflectometer (FWD)
A falling weight Deflectometer fabricated in the Transportation Engineering section of Civil Engineering Department was used for evaluation of precast concrete block pavement laid on the bed of Accelerated Pavement Test Facility.

4.2.3 Construction of test pavement
4.2.3.1 Test pavement
The central area 12m long and 2.1m wide between the two guide rails of the APTF is available for accelerated testing of model pavements. The wheel moves at a constant speed of 6km/hour over the central 12m length.

4.2.3.2 Materials
Materials used in the test for evaluating the performance of precast concrete block under Accelerated Pavement Test were same as those used in the Plate Load Test.

4.2.3.3 Subgrade
The subgrade soil was placed in layers on top of naturally compacted lateritic soil at the optimum moisture content and each layer was compacted by a plate compactor to the required density. The total thickness of subgrade was 828mm (Figure 2). Sand cone replacement method (BIS, 1966) was used to determine the compacted density of each layer.

4.2.4.3 Subbase and blocks
WMM subbase was used in two different thicknesses of 138mm and 300mm (Figure 2). The required quantity of WMM aggregates of different fractions was mixed at optimum moisture content and placed on the compacted subgrade to obtain a compacted thickness of 135mm. The aggregate was then compacted with a plate vibrator. After compaction, field density and moisture content were checked by sand cone replacement method (BIS, 1966). The thickness of the compacted WMM subbase was found as 138mm against the planned thickness of 135mm. The process of placing bedding sand and blocks was same as that adopted in plate load test method.

Before carrying out FWD and Accelerated Load tests on the pavement, thirty joint were selected randomly and their widths were measured with a slide caliper having a least count of 0.02mm. The mean and standard deviation of the joint width were 5.166mm and 2.653mm respectively. FWD and Accelerated Pavement tests were then carried out on the prepared CBP pavement.

For the second test in which the thickness of WMM was proposed as 300mm, concrete blocks, bedding sand as well as WMM laid earlier were removed from the test pit. A part of the subgrade also was removed to accommodate WMM of compacted 300mm in place of 138mm used in the first test. Identical process of placing WMM, bedding sand and concrete blocks was adopted as in the case of the first test. The joint widths were measured and the mean and standard deviation were 6.02mm and 2.22mm respectively.

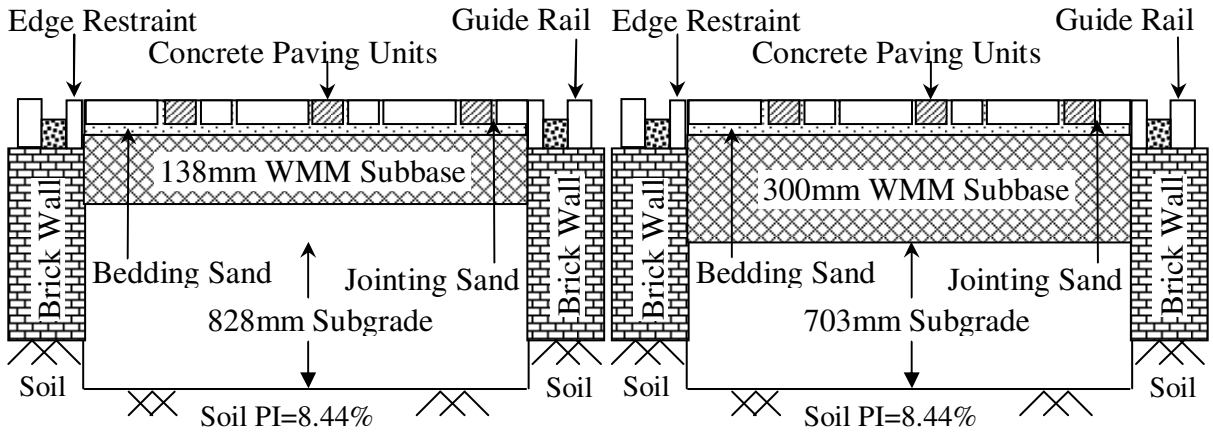


Figure 2. Precast Concrete Block Pavement with thicknesses of 138 and 300mm of WMM Subbase

5. TEST PROCEDURE

5.1 Plate load test

5.1.1 CBP without jointing sand

Concrete blocks of 80mm thickness were then laid over the bedding sand of average loose thickness of 50mm in herringbone pattern keeping the joint widths between 2mm and 4mm. A plate vibrator was made to pass over the blocks for five passes which compacts the sand under the blocks and ensures that the blocks are seated properly. This also allows some of the bedding sand to move into the gap between the blocks. The average loose thickness of 50mm becomes 40mm after compaction. Plate load test was carried out on concrete block pavements with and without jointing sand and deflection readings were taken at distances of 0, 200, 300, 600, 900 and 1200 millimeters respectively (Figure 3) from the center of the loading.

5.1.2 CBP with jointing sand

After testing of blocks without jointing sand, jointing sand was spread over on the blocks and then swept into the openings with a brush. When the joints were completely filled with the jointing material, plate vibrator was made to pass over the blocks. This pushes the jointing sand deep into the gap between the blocks. Then more jointing sand was brushed into the gap and the plate vibrator was again passed over the blocks till the gap was completely filled with jointing material. Sand vibrated into the joints was expected to be in the densest state to offer greater frictional resistance due to relative displacement among the blocks.



Figure 3. Arrangement of dial gauges at radial distances from the center

5.2 Accelerated pavement test

Total numbers of repetitions of 40kN wheel load were 4000 and 6000 passes for 138mm and 300mm of WMM respectively. During the test, rutting along the wheel paths and deflections under FWD were measured at regular intervals of load repetition. The dual wheel moves to and fro over the same path without lateral wander.

5.2.1 Measurement of rutting
Permanent deformation was measured under each of the dual wheels with reference to a fixed datum and the average of the two readings was taken as the rutting of the pavement.

5.2.2 Measurement of deflection with FWD
Surface deflections were measured on the model pavements at radial distances of 0, 300, 600 and 900 mm from the center of loading plate of FWD, 300mm diameter.

6. RESULTS AND DISCUSSION

6.1 Plate load test
The results of the test as detailed in section 5.1 of the paper are presented in Figure 4 and 5.

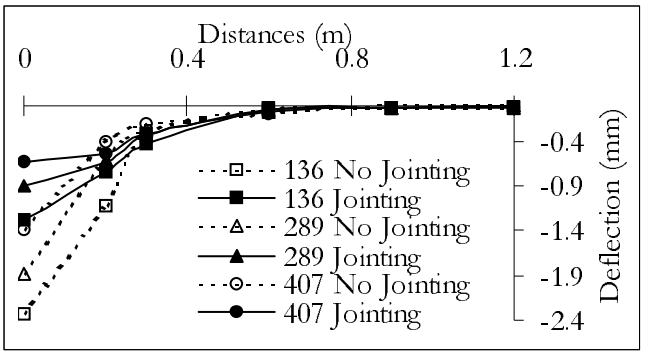


Figure 4. Deflection of Pavement with and without jointing sand with different thickness of WMM

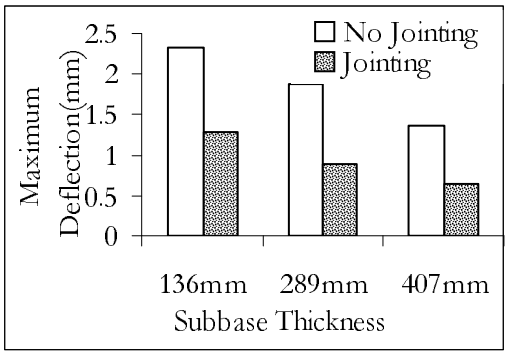


Figure 5. Deflection of pavement with different thickness of subbase

6.1.1 Analysis of test results
6.1.1.1 Effect of subbase thickness and jointing sand on CBP
Figure 4 shows the deflected shape of the pavement for the different thicknesses of subbase considered with and without the jointing sand in between the blocks. Figure 5 shows that the maximum deflection of CBP without jointing sand is significantly higher than that with the jointing sand. Figure 5 clearly shows that the jointing sand reduces the maximum deflection of the pavement by about 45%, 53% and 54% for WMM thicknesses of 136mm, 289mm and 407mm respectively. The reduction occurs because the jointing sand interlocks the pavement and the entire concrete block layer behaves as a single layer. Hence, concrete block layer together with the subbase and subgrade can be considered as components of a three-layer elastic system to evaluate the equivalent elastic moduli of different layers for developing the structural parameters for pavement design.

6.1.1.2 Elastic modulus of pavement layers
For the present study, the CBP consists of 80mm of concrete blocks and granular layer of 136mm, 289mm and 407mm with a compacted bedding sand of 40mm. The pavement was treated as a three-layer system in which CBP formed the top layer, the bedding sand with WMM and the subgrade formed the second and third layers respectively. The deflection data taken at different distances was used for backcalculation of pavement moduli.

In the present study, BACKGA (Reddy et al., 2000), a Genetic Algorithm (GA) based program developed by the Transportation Group of the Institute for the backcalculation of effective layer moduli of flexible pavements was used for the backcalculation. Though the program was developed for

the evaluation of flexible pavement for heavy traffic pavements, it was also found to be valid for the range of the thickness used in the present investigation (Ryntathiang, 2005).

By using the computer program, the backcalculated moduli for the test module pavement deflections of the studied pavement structures are presented in Table 4.

Table 4. Elastic Modulus of Pavement Layers

Thickness of WMM subbase	Computed Elastic Modulus (MPa)		
	Block	WMM	Subgrade
176mm	692	109	100
329mm	1451	170	100
447mm	3299	222	100

It may be seen from Table 4 that the block layer modulus increased with increase in subbase thickness. When load is applied to an individual block, they have no load spreading capacity when there is no jointing sand (Huurman, 1997). The block layer as a whole will possess certain load spreading capacity if the individual blocks are interconnected by shear connectors. It is, therefore, important that the gaps between the blocks be kept as narrow as possible with spaces between 2 to 4mm and should be filled with sand in a densest state which acts as shear connectors upon relative deformation. Where the deflection is large, there is a relative rotation between the two neighboring vertical faces as shown in Figure 6. The rotation brings about widening of the lower part of blocks. Since the jointing sand cannot take tensile stress, lower part of the block is free of any frictional stress and hence does not participate in load transfer. For thin subbases, deflections are large causing large rotation of the block and consequent loss of friction. Weak edge restraint, wide joints, and the jointing sand not fully compacted may also give rise to lower elastic modulus of the block.

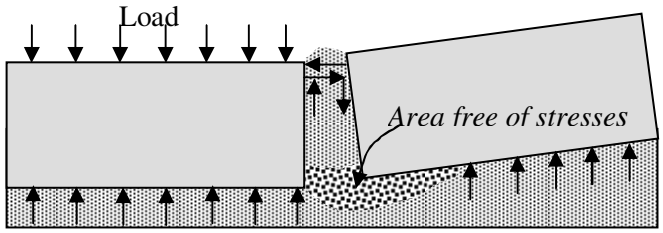


Figure 6. Load spreading in concrete block layer due to joint stresses

6.1.1.3 Equivalent elastic modulus of WMM subbase

Table 4 shows that the modulus of the granular subbase in the CBP increases with increase in the thickness of the granular layer. In order to explain this property of the granular layer, the K-theta model (Equation 1) and the equation given by Equation 2 was examined in the light of observation made by Uzan (1985),

$$MR = k_1 \theta^{k_2} \quad (1)$$

$$MR = k_1 \theta^{k_2} \sigma_d^{\ k_3} \quad (2)$$

Where MR = Resilient modulus of granular material

θ = Sum of principal stresses ($\sigma 1 + 2\sigma 3$)

σ_d = Deviatoric stress ($\sigma 1 - \sigma 3$)

k_1, k_2 & k_3 = Material parameters.

It was observed that resilient modulus (Figure 7) decreases at constant confining pressure with increase in vertical strain whereas k-θ model gives higher modulus with higher values of vertical strain at constant confining pressures. Hence k-θ model is found to be deficient in predicting modulus of granular layers. Figure 7 shows that Equation 2 reasonably predicted experimental results. Therefore, Equation 2 rather than Equation 1 should be used for characterizing modulus of granular materials. Vertical strains were computed by the author at the mid-point of the three granular subbases below the center of loaded plate. FPAVE, an elastic layer computer programme (Das, 1998) was used for computation of stresses due to applied load at the mid point of the subbases vertically below the center of the loaded plate. Stresses due to self-weight were also added to those computed stress due to applied load taking Poisson's ratio of 0.35 for the granular layer. It was found that 447mm subbase has much lower vertical strain than the 176mm subbase (Figure 8). Accordingly, thicker subbases have higher modulus as observed by Uzan (1985) in triaxial test results. It thus appears that Equation 2 should be used for characterising granular subbase. The values of k_1, k_2 and k_3 were obtained from values of θ and σ_d at the mid points of the granular layer and were obtained as 66.834, -0.94 and 0.403.

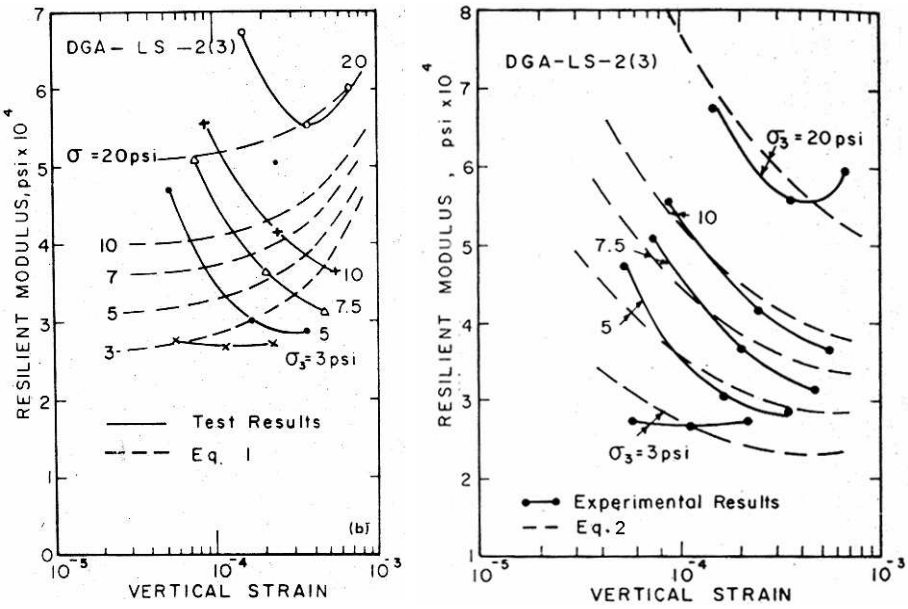


Figure 7: Resilient modulus with vertical strain using Equation 1 and 2 for dense graded aggregate (After Uzan, 1985)

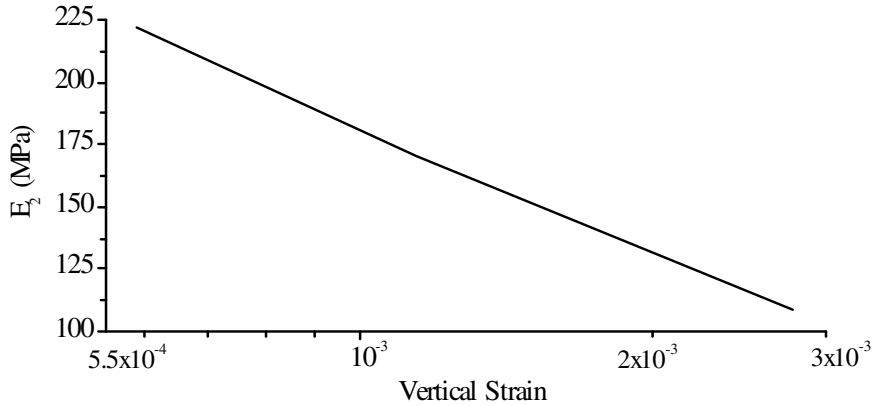
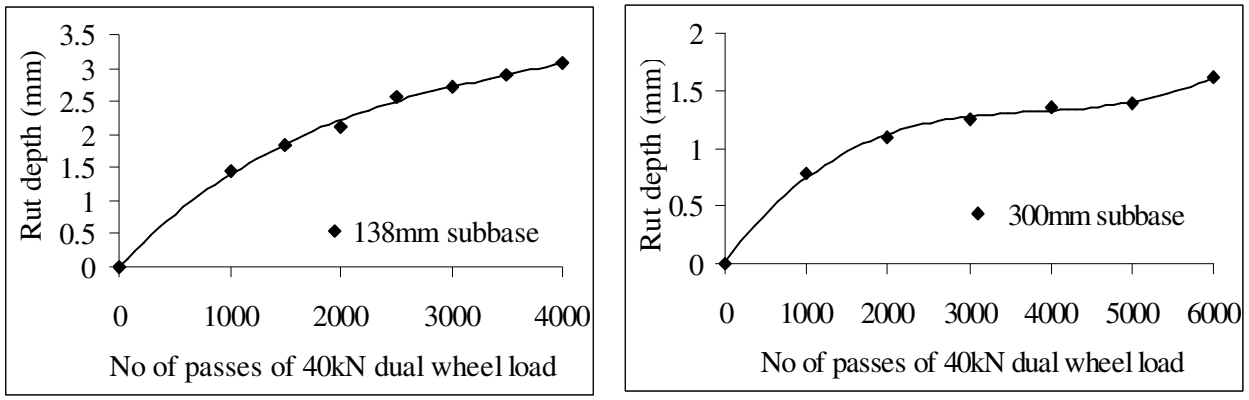


Figure 8. Equivalent elastic modulus of granular subbase with vertical subgrade strain

6.2 Accelerated test

Result of accelerated test as described in section 5.2 is presented below.



(a) (b)

Figure 9. Rut depth of CBP with 138mm and 300mm of WMM subbase

6.2.1 Discussion

Figure 9 shows that CBP constructed with a higher thickness of WMM subbase undergoes less rutting than the one with 138mm. It is obvious that the subbase of higher thickness reduces the vertical stress transmitted to the subgrade because of the increased load spreading capacity of the thicker subbase. The reduction in rutting is about 56%.

Deflection values from FWD test at different repetitions of wheel loads for the two subbases are given in Table 5. These were used for backcalculating of elastic moduli of different layers by BACKGA programme.

In order to develop structural parameters for design of precast concrete block pavements, it is necessary to evaluate the equivalent modulus of different layers. The CBP used in the accelerated test facility consists of 80mm of concrete block and granular subbase of 138mm and 300mm over a compacted bedding sand of 40mm. The subgrade consists of soil compacted to a modified compaction of 98% or higher. The pavement was modeled as a three-layer system in which CBP formed the top layer, the bedding sand with WMM and the subgrade formed the second and third layers respectively. Table 6 shows the results of backcalculation.

Table 5. FWD readings during accelerated pavement test

No of Passes	1st Series (178mm WMM subbase)				2nd Series (340mm WMM subbase)			
	Radial distances (mm)				Radial distances (mm)			
	0	300	600	900	0	300	600	900
0	0.84195	0.5761	0.02414	0.01022	0.69233	0.31487	0.06315	0.03696
1000	0.84970	0.52546	0.01338	0.01173	0.74286	0.34581	0.07778	0.02404
2000	0.83446	0.58265	0.017	0.01321	0.72447	0.33640	0.07862	0.02597
3000	0.81145	0.47959	0.01436	0.00930	0.72316	0.44338	0.11540	0.03953
4000	0.80469	0.51444	0.02196	0.01379	0.71760	0.40680	0.11204	0.03559
5000					0.71641	0.38386	0.08916	0.03004
6000					0.72612	0.38045	0.08980	0.03133

Table 6: Equivalent elastic modulus of CBP for the two series of test

No of Passes	1st Series (178mm WMM subbase)			2nd Series (340mm WMM subbase)		
	Concrete block	Subbase	Subgrade	Concrete block	Subbase	Subgrade
1000	2440	90	100	1434	164	100
2000	2515	90	99	1489	174	100
3000	3025	91	100	3938	104	100
4000	2960	92	99	3415	120	100
5000				2816	134	100
6000				2508	136	100

6.2.2 Equivalent elastic modulus of block layer

Table 6 shows that block moduli are lower in the beginning and increase with repetitions and finally tend to stabilise to some constant values after some repetitions. The moduli of the two block layers at the termination of load repetitions were 2960MPa and 2508MPa for WMM subbases of 178mm and 340mm thickness respectively. With increase in subbase thickness, equivalent block layer modulus should increase as found in plate load test in section 6.1.1.2 but the results are to the contrary. The reduction in equivalent elastic modulus is due to higher joint widths that existed between the blocks. This was found by taking measurement at thirty randomly selected locations. The average joint widths of CBP laid over 138mm and 300mm WMM subbase were 5.166mm and 6.02mm respectively. It was also reported by other investigators (Knapton and O' Grady, 1983; Panda and Ghosh, 2002b) that an increase in average joint width of CBP adversely affected the performance of CBP. It was found that even when joint widths exceeded 4mm, there was a good interlocking showing a reasonably high value of equivalent elastic modulus for the block layer.

6.2.3 Equivalent elastic modulus of subbase layer

Table 6 shows that the subbase modulus changes in the beginning and were stabilises to a constant values after some load repetitions. Similar finding was reported by Uzan (1985) and described in section 6.1.1.3.

6.2.4 Equivalent elastic modulus of subgrade layer

The backcalculated elastic modulus of the subgrade was found to be about 100MPa. To examine the validity of the modulus, Dynamic Cone penetration test was carried out and the corresponding CBR was found as 9.85% (Livneh, 2000). Considering Shell's equation for elastic modulus of subgrade (SHELL, 1978) from the CBR, the above value of the subgrade modulus appears to be reasonable.

7. PERFORMANCE CRITERIA

Plate bearing and accelerated pavement tests on concrete block pavement (CBP) established that such pavements performed in a manner which were similar to a flexible pavement (Shackel, 1980, 1982; Seddon, 1980; Miura et al., 1984; Houben and Jacobs, 1998).

For flexible pavements (IRC, 2001), vertical subgrade strain (ε_z) is considered as an indicator of the rutting behaviour of flexible pavement. For design of CBP, use of ε_z has been selected as design criterion in the present investigation. A reliability level of 50% (AASHTO, 1993) is adopted for producing design charts for low volume roads. Based on a field study of pavements with thin bituminous surfacing, Reddy and Pandey (1992) proposed following vertical subgrade strain criterion for 50% reliability considering 20mm as the limiting value of rutting along the wheel path.

$$N = 3.0599 \times 10^{-7} \left(\frac{1}{\varepsilon_z} \right)^{4.5337} \quad (3)$$

Where N = Cumulative repetition of standard axle
ε_z = Vertical subgrade strain

Equation 3 was used for selecting thickness of subbase for developing a design chart.

7.1 Elastic moduli of pavement layers

7.1.1 Concrete block layer

Plate load test indicated that equivalent modulus of concrete block layers ranged from 700MPa to 3300MPa as shown in Table 4 for subbase thickness varying from 136mm to 407mm. An accelerated pavement tests give an elastic moduli of 2500MPa after 6000 repetitions of standard axle load of 40kN over 340mm WMM subbase. It was also observed that average joint width was about 5mm or greater whereas the jointing sand had a maximum size of 1.18mm. Large joint width reduces modulus value because of lower interlocking. Had the block been machine made, uniform dimensions would have resulted in joint width of 2mm to 4mm resulting in better interlocking and higher modulus. Considering the above, an equivalent elastic modulus of 1500MPa appears to be most suitable for design of concrete block pavement.

7.1.2 Subbase modulus

SHELL's equation (SHELL, 1978) given below was adopted in the present investigation for assigning moduli to a granular layer.

$$E_2 = k \times E_3 \quad (4)$$

Where $k = 0.2(h_2)^{0.45}$

E_2 and E_3 = Elastic modulus values of granular layer and subgrade respectively and

h_2 = Thickness of granular layer in mm.

7.1.3 subgrade modulus

The Subgrade modulus (M_R) for thickness design may be estimated from Lister and Powell's (1987) equations given below.

M_R (MPa) = 10 x CBR for CBR of $\leq$ 5 percent (5)

M_R (MPa) = 17.6 x $(CBR)^{0.64}$ for CBR of > 5 percent (6)

8. DEVELOPMENT OF DESIGN CHART

Based on the available literature and the data obtained in the present research, design charts for low volume roads having $5x10^4$ to $2x10^6$ repetitions of standard axles are proposed. Several combinations of pavement sections were analysed using the computer program FPAVE developed by IIT Kharagpur (Das, 1998) to determine the vertical subgrade strain (ε_z). Values of ε_z were computed at the top of subgrade, vertically below the center of standard dual wheel loads (40kN) for tyre pressure of 0.56MPa. The Poisson's ratios of the top layers (concrete blocks with jointing sand), subbase layer and subgrade were taken as 0.3, 0.35 and 0.35. The subgrade modulus was calculated as given by Equations 5 and 6 and the subbase modulus were obtained from the Equation 4.

Since the thicknesses of concrete blocks were kept constant, the thickness of granular material was varied so that the computed limiting vertical strain (Equation 3) for rutting for different levels of traffic was equal or less than that given by Equation 3. Figure 10 shows the design charts of concrete block pavement (CBP) where rutting was considered as the failure criteria.

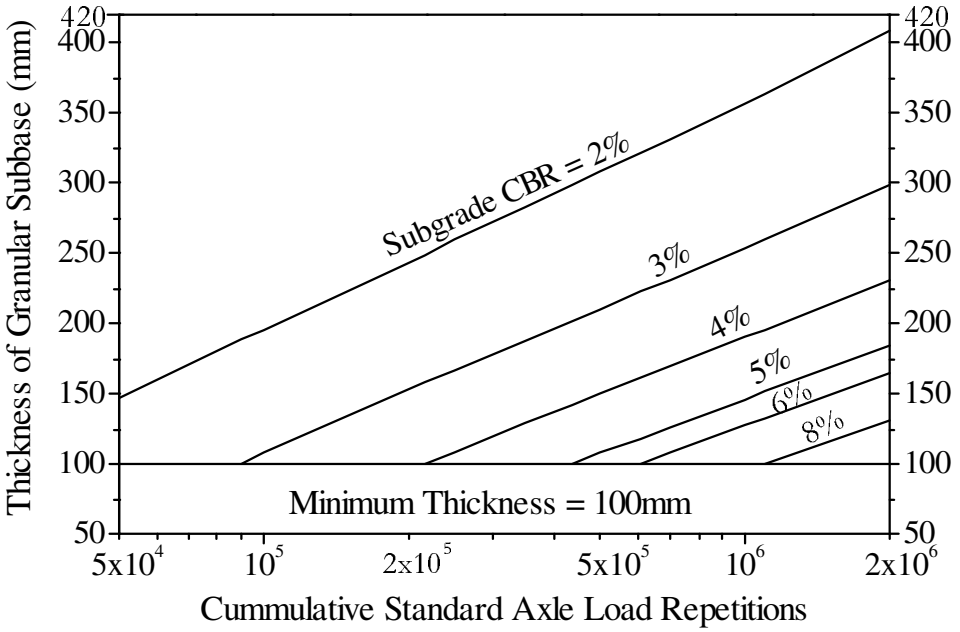


Figure 10. Design chart for precast concrete block pavement (CBP) for 80mm thickness of Blocks

9. CONCLUSIONS

- Increase of WMM subbase thickness from 136mm to 289mm and 407mm reduces deflection significantly.
- The use of jointing sand between the blocks reduces the deflection of the pavement by about 45% to 54% for thicknesses of WMM varying from 136mm to 407mm.
- The modulus of the concrete block layer ranges from 700MPa to 3300MPa.
- The modulus of WMM for its different thicknesses ranged from 109MPa to 222MPa.
- Equivalent elastic modulus of concrete block layer increase with increase in subbase thickness.
- Uzan model gives a better estimate of the modulus of the granular subbase below the concrete blocks rather than the K-θ model.
- CBP was found to have better rutting resistance when laid over subbase of higher thickness.
- Joint width affects the load spreading capacity of CBP, Larger is the joint width, lower is the load spreading capacity of the concrete block layer.

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